PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference XA1891	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/GB2005/001224	International filing date *(day/month/year)* 29.03.2005	Priority date *(day/month/year)* 26.03.2004
International Patent Classification (IPC) or national classification and IPC INV. H01Q15/08 H01Q19/06 H01Q15/23 H01Q1/28 H01Q25/00		
Applicant BAE SYSTEMS PLC et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 7 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in electronic form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the report
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☒	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
26.01.2006	02.05.2006
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Jäschke, H Telephone No. +49 89 2399-7139

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2005/001224

Box No. I Basis of the report

1. With regard to the **language**, this report is based on

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3(a) and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4(a))
   - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a))

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

4-11	as originally filed
1-3, 3a	filed with telefax on 26.01.2006

Claims, Numbers

1-13	filed with telefax on 26.01.2006

Drawings, Sheets

1-7	as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☒ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☒ the claims, Nos. 14
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-13
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-13
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-13
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:

D1: US 2003/006941 A1 (EBLING JAMES P ET AL) 9 January 2003 (2003-01-09)

The document D1 is regarded as being the closest prior art to the subject-matter of claim 1 and shows:

An antenna, comprising a first group of part-spherical dielectric lenses (D1, paragraph [0036]; Fig. 9, feature 12)
each supported on a first, substantially annular portion of a conducting ground plane (D1, paragraph [0036]; Fig. 9, feature 66.1), *each of the lenses of the first group having a plurality of associated switchably selectable antenna feed elements* (D1, paragraph [0030]) *antenna feed elements* (D1, paragraph [0036]; Fig. 10, feature 14) *disposed around the periphery of the lens for injecting signals into and/or receiving signals emerging from at least one sector of the lens* (D1, Fig. 10, feature 14), *wherein*
lenses of the first group and their associated feed elements have different orientations and are operable to provide coverage in respect of different regions (D1, paragraph [0036]; Fig. 9), *and a second group of one or more spherical or part-spherical dielectric lenses and associated switchably selectable antenna feed elements, oriented and operable to provide coverage to a region other than those covered by lenses of the first group* (D1, paragraph [0036]; Fig. 9, features 12.2, 66.2).

The subject-matter of claim 1 differs from this known D1 in that the *annular portion of* the *conducting ground plane surrounds a well-like portion of the antenna* and
the *second group of one or more spherical or part-spherical dielectric lenses and associated switchably selectable antenna feed elements located within said well-like portion of the antenna.*

The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

The problem to be solved by the present invention may be regarded as how to reduce the overall height of the antenna.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons as the introduction of the well-like portion is not obvious or hinted at by the pior art.

Claims 2-13 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII

1 To meet the requirements of Rule 6.3(b) PCT, the independent claim should be properly cast in the two part form, with those features which are part of the prior art (see D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and the subject-matter, for which protection is sought, being placed in the characterising portion (Rule 6.3(b)(ii) PCT).
The remaining claims should be adapted to this new claim.

2 It appears appropriate to incorporate reference numerals in the claims to features in the drawings. The technical features of the claims would be rendered more intelligible by relating these features to the corresponding features of the drawings (Rule 6.2(b) PCT). This applies to both the preamble and characterising portion.

3 The obviously unnecessary statement in the description at page 11, lines 23-25, should be deleted (Rule 9.1 (iv) PCT).

AN ANTENNA WITH PARTIALLY SPHERICAL DIELECTRIC LENSES

The present invention relates to an antenna and in particular to a multiple beam antenna. More particularly, but not exclusively, the invention relates to a low-profile multiple beam antenna operable to provide at least hemispherical coverage.

Lens-based multiple beam antennae are known to offer a viable and lower cost alternative to phased array antennae for use in a range of applications, both military and non-military. In particular, multiple beam antennae with electronically switched beams and spherical dielectric lenses are known which are able to produce a wide field of coverage while avoiding some of the engineering issues that can arise with phased array antennae.

In US 2003/0006941, a multiple beam antenna comprises a hemispherical dielectric lens with multiple associated switchably selectable antenna feed elements, the lens being mounted adjacent to a reflector and being operable to provide directional coverage.

Multiple beam antennae may use spherical or partially spherical dielectric lenses, e.g. hemispherical lenses, in particular lenses known as "Luneburg" lenses having a continuously varying or step-graded index profile. In a known arrangement, a so-called "virtual source" antenna comprises a half (hemispherical) Luneburg lenses mounted adjacent to a conducting ground plane. When signals are injected into the lens at a certain angle by one of a number of switchable radiating elements disposed around a portion of the lens, radiation emerges from the lens, is reflected off the ground plane, and re-enters the lens at a different angle, so simulating the effect of a virtual source of radiation as if a full spherical Luneburg lens were being used.

Several methods of fabricating Luneburg lenses, capable of operating at microwave frequencies, have been developed. The most common method uses a hemispherical shell construction yielding an approximate stepped or graded index profile.

US Patent number 5,781,163 describes an antenna arrangement based upon hemispherical dielectric lenses arranged as a collinear array of half Luneburg lenses mounted on a common ground plane, providing a low profile,

low radar cross section, high-gain antenna. Each hemispherical lens is fed by a single radiating feed element mounted on a feed arm. Beam pointing is achieved by rotating the ground plane and moving all radiating feed elements simultaneously along their feed arms.

In one particular type of large array of full or half Luneburg lenses, it has been proposed to build a radiometer with exceptionally high gain. The antenna in that case was designed to operate at low microwave frequencies, typically less than around 5 GHz. Although low radar cross section is not an issue at these frequencies, half Luneburg lenses may be preferred because the ground plane offers a way of mechanically supporting the weight of the lenses. Each lens may be fed by a single radiating element or clusters of elements that are mounted on feed arms and are mechanically steered.

In known arrangements above, in order to provide at least hemispherical coverage, a certain amount of mechanical steering is required to the antenna.

From a first aspect, the present invention resides in an antenna, comprising a first group of part-spherical dielectric lenses each supported on a first, substantially annular portion of a conducting ground plane surrounding a well-like portion of the antenna, each of the lenses of the first group having a plurality of associated switchably selectable antenna feed elements disposed around the periphery of the lens for injecting signals into and/or receiving signals emerging from at least one sector of the lens, wherein lenses of the first group and their associated feed elements have different orientations and are operable to provide coverage in respect of different regions, and a second group of one or more spherical or part-spherical dielectric lenses and associated switchably selectable antenna feed elements located within said well-like portion of the antenna, oriented and operable to provide coverage to a region other than those covered by lenses of the first group.

Utilising the spherical symmetry of the lens, a relatively wide field of view may be provided by each lens, ideally without blockage between the switchably selectable antenna feed elements. Moreover, deployment of one or more lenses in the well-like region of the antenna enables a greater angle of coverage to be provided without increasing the overall height of the antenna arrangement above a mounting surface. The conducting ground plane may further comprise

a second portion inclined differently to the first portion, and the second group of one or more lenses comprises at least one part-spherical lens supported by the second portion of the ground plane, for example where the second portion of the ground plane forms the side-walls of the well-like portion of the antenna.

In an alternative arrangement, rather than mounting part-spherical lenses on ground plane walls of the well-like portion, a single spherical lens may be located within the well-like portion of the antenna to provide equivalent coverage to an arrangement of part-spherical lenses mounted within the well.

Preferably, the first portion of the ground plane surrounds a substantially square well-like portion and the first group of one or more lenses comprises four part-spherical lenses disposed with substantially equal spacing around the well-like portion. Where the second portion of the ground plane forms the side-walls of a square well-like portion of the antenna, preferably inclined at approximately 45 degrees to the corresponding sections of the first portion of the ground plane, one part-spherical lens may be mounted on each of the four walls of the well.

In a further preferred embodiment of the present invention, the conducting ground plane further comprises a third portion inclined differently to the first and second portions and the antenna further comprises a third group of one or more part-spherical dielectric lenses, each having a plurality of associated switchably selectable antenna feed elements, supported by the third portion of the conducting ground plane and operable to provide coverage to a different region to those covered by the first and second groups of lenses.

Preferably antenna feed elements are located on the surface of each lens or at a convenient distance away from the lens surface, preferably on the focal surface of the lens. Antenna feed elements of preferred antennae may either transmit a beam into any desired direction (transmit mode) or receive a signal from any desired direction (receive mode) from within the solid angle of view of the antenna, preferably at least hemispherical.

Conveniently antennae are mounted on flat surfaces. By arranging hemispherical lenses or combinations of hemispherical and spherical lenses in this manner, the antenna extends only half as far above a surface as was

previously the case compared with conventional antennae employing full spherical lenses or reflectors.

CLAIMS

1. An antenna, comprising a first group of part-spherical dielectric lenses each supported on a first, substantially annular portion of a conducting ground plane surrounding a well-like portion of the antenna, each of the lenses of the first group having a plurality of associated switchably selectable antenna feed elements disposed around the periphery of the lens for injecting signals into and/or receiving signals emerging from at least one sector of the lens, wherein lenses of the first group and their associated feed elements have different orientations and are operable to provide coverage in respect of different regions, and a second group of one or more spherical or part-spherical dielectric lenses and associated switchably selectable antenna feed elements located within said well-like portion of the antenna, oriented and operable to provide coverage to a region other than those covered by lenses of the first group.

2. An antenna according to Claim 1, wherein the second group of one or more lenses comprises a spherical lens, located within said well-like portion of the antenna.

3. An antenna according to Claim 1, wherein the conducting ground plane further comprises a second portion inclined differently to the first portion, and wherein the second group of one or more lenses comprises at least one part-spherical lens supported by the second portion of the ground plane.

4. An antenna according to Claim 3, wherein the second portion of the ground plane is arranged to form the side-walls of said well-like portion.

5. An antenna according to any one of claims 1 to 4, wherein the first portion of the ground plane surrounds a substantially square well-like portion and wherein the first group of one or more lenses comprises four part-spherical lenses disposed with substantially equal spacing around the well-like portion.

6. An antenna according to Claim 5 when dependent upon Claim 4, wherein the second group of one or more lenses comprises four part-spherical lenses each one supported on a different side-wall of the well-like portion.

7. An antenna according to Claim 3 or Claim 4, wherein the conducting ground plane further comprises a third portion inclined differently to the first and second portions and wherein the antenna further comprises a third group of one or more part-spherical dielectric lenses, each having a plurality of associated switchably selectable antenna feed elements, supported by the third portion of the conducting ground plane and operable to provide coverage to a different region to those covered by the first and second groups of lenses.

8. An antenna according to any one of the preceding claims, wherein each of said antenna feed elements is located at a point on the focal surface of the respective dielectric lens.

9. An antenna according to any one of the preceding claims, further comprising a switching network operable to select one or more of the antenna feed elements associated with said groups of lenses.

10. An antenna according to Claim 9, wherein said switching network is a binary switching array.

11. An antenna according to any one of the preceding claims, further comprising a frequency-selective surface arranged to provide an enclosure for said lenses of the antenna and operable to permit passage of signals used by the antenna but to absorb or reflect other signals.

12. An antenna according to Claim 11, wherein said frequency-selective surface is arranged to have an aerodynamically low-drag profile.

13. An antenna according to any one of the preceding claims, operable to provide simultaneously a plurality of independent radiation beams in different directions.